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Chlorophyll-a Concentration used in Androscoggin River Model

Background

The US Clean Water Act requires states to adopt Water Quality Standards (WQS) for all public waters. WQS are composed of three parts, 1) designated uses, 2) criteria to support the uses, and 3) an anti-degradation statement. Maine's WQS are contained in its Water Classification Program 38 MRSA section 464 et seq..

The general provision section 464(4A(4)) Specifies that 'the Department may not issue a waste discharge license for discharges to waters of the State that impart color, taste, turbidity, toxicity, and radioactivity or other properties that cause those waters to be unsuitable for the designated uses and characteristics ascribed to their class'. The Androscoggin River is classified as Class C in the area of Gulf Island Pond. Class C standards specify that the waters shall be suitable for the designated use of 'drinking water supply after treatment; fishing; recreation in and on the water (which includes swimming) ; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as a habitat for fish and other aquatic life'. Furthermore, the anti-degradation statement requires that the 'waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community'.

Algae Blooms and Gulf Island Pond

High concentrations of total phosphorus lead to excessive concentrations or 'blooms' of algae. Decomposition and respiration of excessive populations of algae, i.e. a bloom, lead to diurnal dissolved oxygen fluctuations in mixed surface layers and constant seasonal depletion in unmixed deeper stratified waters. Lowered concentrations may be below the water quality criteria, necessary to support the designated uses of 'fishing' and 'habitat for fish and other aquatic life' and to 'support indigenous species of fish' as required for Class C waters. The chlorophyll a concentration, a measure of algae, is an identified component of the water quality model used to evaluate compliance of waste discharges with the dissolved oxygen criteria.

Algae blooms also impart color, increase turbidity, and result in overall conditions that cause waters to be unsuitable for swimming. As a result these waters do not support the designated uses and then are listed by DEP for EPA's 303D list of waters not attaining their Water Quality Standards. Algal blooms are primarily a problem in lakes and ponds because of higher retention time than in rivers, but blooms do occur in some riverine impoundments, such as Gulf Island Pond, when and where they act like lakes. An algal bloom is defined by DEP rule at Chapter 581 as a planktonic growth of algae which causes Secchi disk transparency to be less than 2.0 meters. Algal blooms are also correlated with chlorophyll a concentrations exceeding 8-10 parts per billion (ppb) and total phosphorus concentrations exceeding 15-18 ppb. For more colored waters, elevated chlorophyll a (usually exceeding 8 ppb) is used by DEP staff to confirm the presence of blooms along with Secchi disk

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measurements. The 8 ppb chlorophyll a level is also recommended as a threshold of eutrophy for plankton in EPA's Nutrient Criteria Technical Guidance Manual for Rivers and Streams (2000). The National Council for Air and Stream Improvement, a research arm of the paper industry, cites a value of 10 ppb of chlorophyll a from Chapra (1997) as the threshold between eutrophic and mesotrophic lakes. A letter dated October 1, 2003 to Commissioner Gallagher from Bill Taylor on behalf of the Gulf Island Pond Oxygenation Partnership (GIPOP) argues that the EPA value of 8 chlorophyll a is for eutrophy, which is not the same endpoint as algal blooms. He argues that the EPA chlorophyll action level of 15 ppb is for blooms. In Maine, however, all lakes that are considered eutrophic (for phytoplankton) by DEP, have blooms. As such, the Department does not support using a value of 15 ppb of chlorophyll a to designate attainment with the swimmability standard.

Using all recent data from Maine lakes where both Secchi disk and chlorophyll a were measured and color was less than 30 standard platinum units (spu), Acheron Engineering under contract to GIPOP, developed a regression from which a mean chlorophyll a value of 15 ug/l was calculated for a Secchi disk measurement of 2 m. The correlation between chlorophyll a and Secchi disk, (R^2) was 0.39, considered a weak or poor relationship.

Yet this relationship has been well established in the literature, often on the basis of transformed data. In fact studies of Maine lakes prior to 1986 had demonstrated a correlation between Secchi disk (<2 m transparency), total phosphorus (>15 ppb) and chlorophyll a (8 ppb) that defined a bloom and became statutory criteria for defining blooms in lakes classified as GPB. This classification was terminated in 1986, leaving only lakes that should not bloom as GPA. More data have been gathered since then, and the Department examined the modern dataset to see if the relationship between Secchi disk of 2 m and chlorophyll a was still the same. Natural log and square root transformation of both variables improved the correlation to that generally considered significant ($R^2 > 0.5$). However, none of the datasets were normally distributed, violating one assumption for use of linear regression. Furthermore, treating each data point equally violates the assumption of independence of observations. Clustering by lake MIDAS number addresses this condition, but results in a wide confidence interval for the estimate (chlorophyll a 3-30 ppb). This indicates that the relationship between chlorophyll a and Secchi disk transparency is different among lakes.

Given that Gulf Island Pond is an impoundment of a river, water velocity and turbulence may further change the relationship between chlorophyll a and Secchi disk from that of lakes. The river is also relatively highly colored (>30 spu), which affects the relationship as well. Therefore, it is difficult to determine exactly how much chlorophyll a will result in a Secchi disk transparency of 2m or of a bloom in Gulf Island Pond, although it is expected to be in the range of 8-12 ppb. Given the all the uncertainty, the Department will monitor all of the variables during implementation of the TMDL for GIP in order to better determine the occurrence of blooms following reductions in point source discharges. If blooms persist, additional action will be necessary to meet Water Quality Standards.

References

Acheron Engineering, memorandum of September 25, 2003 to Gulf Island Pond Oxygenation Partnership

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EPA, 2000. Nutrient Criteria Technical Guidance Manual, Rivers and Streams. US. Environmental Protection Agency, Office of Water, Wash. D.C., EPA-822-00-002.

PEARL website <http://pearl.maine.edu/>

William Taylor letter of October 1, 2003 to Commissioner Dawn R. Gallagher

Prepared by Barry Mower, DEP, December 1, 2003

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